IS 5878-3 (1972): Code of Practice for Construction of Tunnels Conveying Water, Part III: Underground Excavation in Soft Strata [WRD 14: Water Conductor Systems]

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CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART III UNDERGROUND EXCAVATION IN SOFT STRATA

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Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART III UNDERGROUND EXCAVATION IN SOFT STRATA

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Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART III UNDERGROUND EXCAVATION IN SOFT STRATA

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 29 December 1972, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The construction of tunnels involves a large number of problems. Because of the great longitudinal extent of the work many different kinds of conditions are encountered which for maximum economy should be treated differently. This standard covers recommendations for the assistance and guidance of the engineers engaged on projects where tunnelling through soft strata is involved. This standard should, however, be used with caution since, due to the very nature of the work, it is not possible to lay down detailed specifications to cover each and every possible case. The discretion of the engineer-in-charge would be required in many cases.

0.3 This standard is being published in parts. Other parts of this standard are as follows:

Part I Precision survey and setting out

Part II Underground excavation in rock

Section 1 Drilling and blasting

Section 2 Ventilation, lighting, mucking and dewatering

Section 3 Tunnelling method for steeply inclined tunnels, shafts and underground power houses

Part IV Tunnel supports

Part V Concrete lining

Part VI Steel lining

Part VII Grouting

0.3.1 This part covers the special problems involved in the underground excavation in soft strata and should be read along with Part II of this standard as the problems common to both types are not dealt with in this part. The sections of Part II dealing with ventilation, mucking, lighting, dewatering and methods for steeply inclined tunnels and shafts shall apply to this part equally.

0.4 This standard is one of a series of Indian Standards on tunnels. Other standards published so far in the series are:

IS : 4081-1967 Safety code for blasting and related drilling operations

IS : 4137-1967 Safety code for working in compressed air

IS : 4756-1968 Safety code for tunnelling work

IS : 4880 (Part II)-1968 Code of practice for design of tunnels conveying water: Part II Geometric design

IS : 4880 (Part III)-1968 Code of practice for design of tunnels conveying water: Part III Hydraulic design

IS : 4880 (Part IV)-1968 Code of practice for design of tunnels conveying water: Part IV Structural design of concrete lining in rock

IS : 4880 (Part VI)-1971 Code of practice for design of tunnels conveying water: Part VI Tunnel supports

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard (Part III) deals with the special problems of underground excavation in soft strata generally. This standard, however, does not cover the innumerable specific problems that arise in the case of excavation in anhydrite rocks, high temperature rocks or in highly swelling and squeezing conditions.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

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*Rules for rounding off numerical values (*revised*).

2.1 Adit — A tunnel or open cut driven from the surface to add to the number of working faces of the main tunnel.

2.2 Benching — The operation of removal of the lower portion of the tunnel profile after the top heading has been excavated.

2.3 Cover — Cover on a tunnel in any direction is the distance from the tunnel profile to the outermost rock surface in that direction. However, where the thickness of the overburden is sizeable, its equivalent (reduced to the same density as rock) weight may also be reckoned provided that the rock cover is more than three times the diameter of the tunnel.

2.4 Cut — The group of holes fired first in a round to provide additional free faces for the succeeding shots.

NOTE — This definition applies only to drilling patterns.

2.5 Detonator — A device for producing detonation in a high explosive charge and initiated by a safety fuse or by electricity.

2.6 Drift — A horizontal tunnel usually of a small cross-section and length, driven either from surface for exploration purpose or from an underground face for any purpose.

2.7 Drill Carriage — A vehicle on which one or more drill booms are mounted to permit the drills to be brought easily to their work site and to be removed before blasting.

2.8 Drilling Pattern — It is an arrangement showing location, direction and depth of the holes drilled into the face of a tunnel.

2.9 Easer — Ring of holes drilled around cut holes and fired after cut holes.

2.10 Explosive — Any mixture or chemical compound which is capable of producing an explosion by its own energy. This includes black powder, dynamite, nitroglycerine compounds, fulminate or explosive substance having explosive power equal to or greater than black powder.

2.11 Heading — The face of the tunnel where actual tunnelling operations are in progress. However, when it is prefixed by ‘ top ’ or ‘ bottom ’ it denotes a part section of the tunnel excavated in advance in line of the intended tunnel.

2.12 High Explosive — An explosive which explodes with detonation and detonates at velocities varying from about 1 500 to 7 500 m/s and produces large volume of gases at exceptionally high pressure.

2.13 Jumbo — A mobile platform with number of decks used at the heading of large tunnels for drilling and also for scaling, roof erection of supports, guniting, shotcreting etc.

2.14 Mucking — The operation of removal of the blasted stones/material after the blast has taken place.

2.15 Overbreak — The portion which gets excavated beyond the lines of the intended profile.

2.16 Primer Cartridge — The explosive cartridge into which the detonator has been inserted.

2.17 Scaling — An operation to remove all loose bits of rock from the blasted surface, after the blasting is over.

2.18 Soft Strata — It is a strata of soft rocks, usually sedimentary or metamorphic, which are jointed and faulted, and which require supports to be installed within a very short period of excavation, but which cannot be easily excavated by hand tools.

2.19 Soils — These are defined as disintegrated rocks which require support immediately after and/or during underground excavation and can be excavated by hand tools.

2.20 Stemming — Insert material packed between the explosive charge and the outer end of the shot hole.

2.21 Stoping — Operations for overhead excavation by drilling from an underground face.

2.22 Trimmer — Holes at the periphery of an excavation, fired to give the excavation its final outline.

3. GENERAL

3.1 The practice of tunnelling in soft strata will vary with the softness of the strata, sub-soil water conditions and the facilities available for construction. The choice of tunnelling method to be adopted would depend upon the response of the strata to the technique adopted, which in turn would depend upon the geometry and area of the tunnel sections also. Various tunnelling methods in vogue for soft strata may be classified into the following three main categories: (however, there would be cases falling between any two of the categories and these cannot be defined).

a) *Firm Ground* — Ground where reasonable bridging period is available for installing the conventional supports. This type includes soft and stratified rocks, such as sand stone, shales, cemented sand and gravel and hard clays.

b) *Soft Ground* — Ground where bridging period is so short that conventional supports cannot be installed. In some cases of this type it may be possible to increase the bridging time by methods like shotcreting. This type includes soft or squeezing clay,

damp sand, certain types of gravels or soft earth, some formations of decomposed and/or treacherous rocks.

c) *Running Ground* — This is the ground which requires special treatment before excavation can be done. It may be highly crushed rock, dry sand and gravel, water bearing sand or gravel, silts and muds.

3.2 Location of Portals — Preliminary work required to establish a tunnel face consists of mainly the following items:

a) Open excavation in overburded and rock or excavation of shaft from the bottom of which the tunnel excavation can start.

b) Arrangement for collection of surface water and its drainage by gravity or pumping.

c) Access roads or rail tracks to mucking areas.

d) Erection of winching and hauling equipment.

e) Establishment of a field workshop, compressors, pumps, water lines, ventilation fans ducts, etc.

3.3 The face from where a tunnel satrts has to be decided with reference to the rock cover. The minimum cover with which tunnel can be started depends on the type and structure of rock mass, the size and shape of the tunnel and the pressure of the water in case of hydro-tunnels.

3.3.1 The length up to which it is economical to adopt an open cut in preference to a tunnel depends on the cost of underground and open excavation and the cost of protective works and maintenance involved.

3.3.2 In some cases, the cost of protective works in open cuts becomes very high. However, open excavation has to be continued up to a point where adequate rock cover is available. Under such circumstances cut and cover sections are found more suitable.

3.3.3 Before taking up the excavation of tunnel its face shall be established and alignment of the tunnel marked in accordance with IS : 5878 (Part I)-1971*.

4. TUNNELLING METHODS IN FIRM GROUND

4.1 The methods of excavation of the tunnel depend on the size and shape of the tunnel, the equipment available and the condition of the formation and the extent of the supports necessary and overall economics. With the development of mechanical tunnelling machines, known generally

*Code of practice for construction of tunnels: Part I Precision survey and setting out.

by the name of mole, the two principal methods of excavation are as follows:

a) Traditional methods, that is, by drilling and blasting.

b) Excavation by tunnelling machines.

4.2 Traditional Methods — The common methods are given in **4.2.1** to **4.2.4.** The technique of tunnelling in soft strata will depend on many factors like size and shape of the tunnel, softness, bridging period (stand-up time), and the nature of the strata whether it is intact, stratified, moderately jointed, blocky and seamy, crushed, squeezing and swelling type, dry or water bearing, etc. However, the excavation shall be suitably supported with temporary wooden supports or permanent steel supports, depending upon the type of strata, the size and shape of the tunnel and the tunnelling method adopted. Sometime, the techniques of rock bolting and shotcreting are employed, individually or in conjunction with each other to support the excavated sections, depending upon the type of strata.

4.2.1 *Full Face* — This method may be found suitable for strata where bridging period is long enough to permit ventilation, mucking and supporting and is recommended for tunnels of small size.

4.2.2 *Top Heading and Benching* — This method is recommended in the case of tunnels where full face method is not suitable. The heading may be excavated and supported, if necessary to full length or part length of the tunnel before benching is started.

4.2.2.1 Top heading may be carried ahead of the bench by a convenient length. The heading may have the full width of the tunnel and may be carried down to the springing line.

4.2.2.2 Where bad roof conditions are known to exist in most of the tunnel length or the diameter is large heading may be excavated to full length.

4.2.3 *Bottom Heading and Stoping* — This method is not suitable for soft strata, unless the strata is stabilized by special treatment.

4.2.4 *Drift Method* — In the case of large size tunnels in soft rock, the method of driving small sized tunnels in the face either as a pilot tunnel, or as side and top drifts, is recommended to enable placement of supports prior to the excavation of the bore.

4.2.4.1 *Wall plate drift* — Both heading and benching or top heading methods may sometimes have to be supplemented by drifts at each side on the spring line, advanced beyond the heading face to receive wall plates. These drifts may be driven where the rock is so bad that only a short advance can be made per pull in the heading. The purpose is to permit

use of wall plates of sufficient length to support the top ribs when the subsequent bench blast is taken. The purpose of holding the ribs in the heading until the side ribs in the bench blast are installed will also be served by providing projecting cantilever beams horizontally above the springing line and secured to the ribs in the previous advance.

4.2.4.2 *Side drift* — The side drift method of attack may be employed in a large size tunnel through bed rock which requires support before mucking. The ' rib, wall plate and post ' type of support may be used. A drift may be driven ahead at each side at subgrade in which the posts and wall plates may be erected. If the strata permits, full face operation may then be carried out and the roof ribs may be quickly erected (before mucking) over the exposed wall plates already erected in advance in the side drifts. In case ground conditions do not permit free operations, multiple drift method shall have to be adopted.

4.2.4.3 *Multiple drift method* — This method which is a combination of side drifts and top drift may be frequently employed to get through crushed rock in fault zones which may behave like earth, even if the rock is compacted enough to require light blasting. There are two different methods as below for achieving this:

a) A crown drift is made first and supported by two vertical posts (to be removed later) and a segment of the steel ribs which would form a part of the ultimate steel ribs. Drifts on either side of the central drift are then made and supported by steel rib segments such that these segments along with the segment over the central top drift would form a complete semicircle above the springing. Where the unnel section is large, the above method may be adopted with five segments instead of three as in the above procedure. Benching would then follow the heading done in three or five segments by multiple drifts.

b) A side drift may be driven through the zone at subgrade on each side. A side support in steel or concrete should be constructed in each drift, with adequate provisions for drainage. Should the height of the side walls be too great to build the concrete wall in a single lift, another side drift may be driven immediately above and the concrete side walls carried on up to spring line as shown in Fig. 1. A top centre drift may be then driven through, with the roof support sufficiently above the proposed position of the main tunnel ribs to provide space for crown bars over the ribs. A short section of the drift roof should be blocked on the crown bars and the drift side posts removed. The top drift may be widened out by means of short shots to connect with the roofs of the side drifts. The main arch ribs may be erected on the steel posts or concreted side walls, lagged and packed. The

crown bars supporting the roof members of the top centre drifts should be securely blocked to the ribs, whereupon the next advance should be made. The support for the main tunnel may be the 'continuous rib' type, usually in two piece form although it may be made of more than two pieces. The type of support for the drifts may be the two piece 'continuous rib' or the 'rib and post' type.

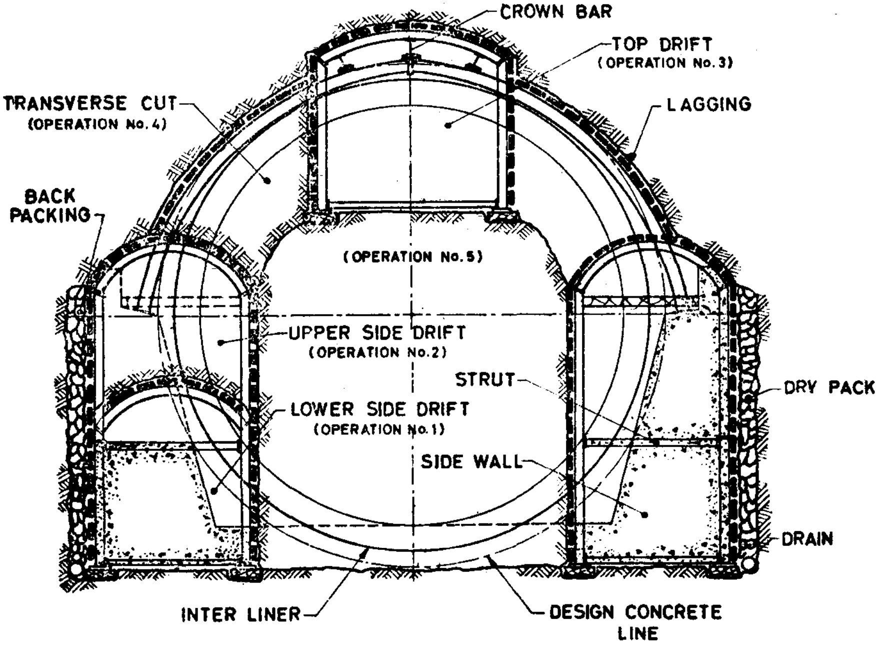

FIG. 1 MULTIPLE DRIFT METHOD

5. TUNNELLING METHODS IN SOFT AND RUNNING GROUND

5.1 Forepoling Method — In the case of soils, either dry or saturated, which require almost instantaneous support, drilling and blasting is never required. Forepoling method is the traditional method and is illustrated in Fig. 2.

5.1.1 In the case of running ground, that is material with no cohesion, such as clean sand or gravel, or highly crushed rock which flows out it may become necessary to hold up the face by breast boards (that is horizontal timber pieces blocking the face, just ahead of the steel supports).

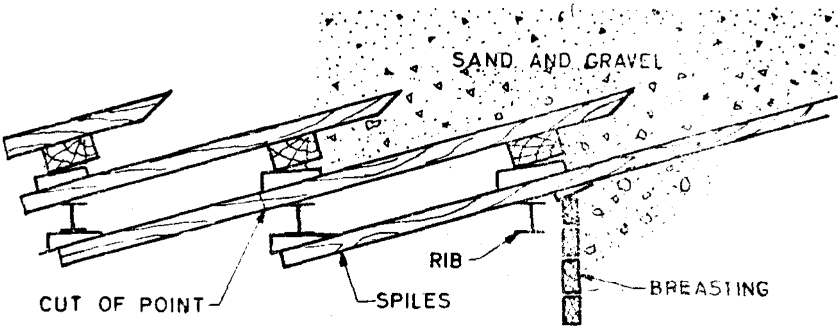

FIG. 2 DIAGRAM OF FOREPOLING METHOD OF SUPPORTING RUNNING GROUND

5.1.2 The boards which are driven ahead to support the ground ahead of the last rib are known as ' spiles ' These may be of timber or of steel. The forepoles act as cantilevers and carry the weight of the ground until their forward ends are supported by the steel rib.

5.1.3 The spiles should be installed as far around the periphery as necessary. The soil should be excavated out after removing the breast boards and the new rib erected in position. Breast boards may then be again refixed on the face. The forepoles should be inserted in such a way that they fan out tangentially from the last rib. In such cases they will not interfere with the tunnel section and it will not be necessary to cut them. They may be embedded in the initial concrete; or the overhanging forepoles may be cut out, if possible, and the process repeated. In such cases the supports should be usually at 600 to 900 mm spacing.

5.2 Tunnelling with Liner Plates — This method may be generally employed for driving steel lined small section drifts or headings on medium soft ground. It may also be adopted for small cross-section drifts even in running ground when combined with compressed air working. The first liner plate should be placed at the crown segment in a pre-excavated cavity at the top and two adjacent liner plates being bolted to it one in each side after the hole has been sufficiently widened. These plates should be temporarily supported by trench jacks or by carefully tightened props. The arch section should be then gradually widened down to the springing line and the liner plate ring so obtained should be wedged outward from wall plates or wall beams placed at the grooves.

5.2.1 The liner plate method may be used in very large tunnels in combination with stiffener rings.

5.3 Needle Beam Method — This method which is a variation of the method described in **5.2** is illustrated in Fig. 3. In this method the full section of the tunnel is broken out. During excavation the plates should be set up one by one, supported by radially set trench jacks or props from a centrally placed longitudinal gird.: called the needle beam which may be fabricated using two heavy steel joists bolted to each other, the space between being filled with hard wood. The length of the needle beam should be chosen to exceed the daily advance by 1·0—1·2 m. It should be placed at the bottom of the top heading, its rear end being supported during the driving by a port from the concrete invert of the tunnel which has already been placed in position. When the needle beam is placed, the trench jacks which formerly stood up on the core should be taken out as the new ones are set from the beam. While in the upper half section timber props may also be used instead of trench jacks, in the lower half steel trench jacks are recommended to counter act the excessive bending deflection of the beam by their restretching especially in bad ground with excessive rock pressure.

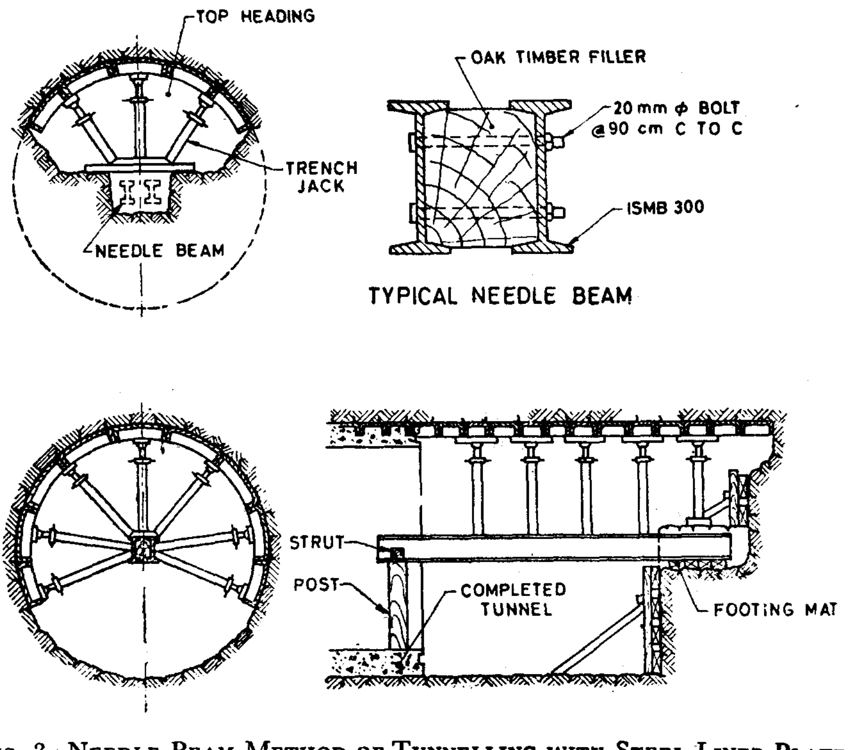

Fig. 3 Needle-Beam Method of Tunnelling with Steel Liner Plates

5.3.1 It is recommended not to excavate sections ahead to distances exceeding one day's concreting in order to avoid development of high rock pressures.

5.3.2 Each row of trench jacks shall be connected by axially placed etchers to prevent its slipping or kicking out on the steel washers.

5.4 Flying Arch Method — In this method (*see* Fig. 4) a top heading is driven, the liner plates of the arch being supported by trench jacks resting on the bench. Each day's drive should be concreted with half round arch forms, handled and filled by hand. A plank footing under the concrete is recommended for a clean even joint. After the heading has been driven about 20 to 25 m the bench should be taken out and the invert concrete placed.

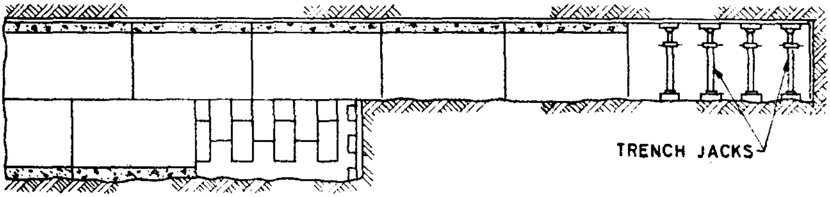

FIG. 4 FLYING ARCH METHOD OF TUNNELING

5.5 Other Methods (Traditional) — In some strata it may be possible to consolidate the ground to be excavated by grouting with cement and/ or chemicals or by freezing the ground. The grouting should be done in an umbrella pattern that is by driving holes inclined away from the periphery to consolidate the strata around the excavation and hold it after excavation till supports are erected. This grouting serves as a forepoling support. This method is of no avail in clays, which do not accept grout.

6. SHIELD METHOD OF TUNNELLING IN CLAYS

6.1 This method of excavation was developed primarily for the excavation of the tube railway tunnels in clay. Basically it is a circular shield of thick steel plates with adequate stiffeners. The excavation of the face is done by hand or pneumatically operated clay spades in sections. The shield is pushed into the excavation by hydraulic jacks, pressing against previously erected linings. The lining conventionally was cast-iron blocks, usually 60 cm long. The segments are held in place by bolts both longitudinally and transversely. As soon as the lining segments are erected and bolted up, the gap between the lining and clay is filled up with pea (passing 13 mm size) gravel blown by pneumatic grouters. This is

followed by packing with cement grout. The lined tunnel thus affords the necessary reaction for the hydraulic jacks to push forward the shield into the clay band. The shield affords complete safety and where the face is stable and does not require breasting, rapid progress has been attained. Recently, the cast-iron segments have been replaced on some projects by segments of precast concrete of high strength usually 421·8 kg/cm² using similar bolted connections, gravel packing and grouting.

7. EXCAVATION BY TUNNELLING MACHINES

7.1 A variety of these machines have been developed and built in recent times. These machines are not yet in common use in India because of the high capital costs and non-availability of indegenious cutters.

7.1.1 Basically the tunnelling machines excavate the strata by cutting through it. The cutting is done by rotation of drum or a circular disc, or a circular arm on which are mounted the cutting teeth or wheels or tips. These are of special tungsten carbide or industrial diamonds. The lateral force to press the cutters against the face is provided by hydraulic systems. The machine cuts out the rock, like a drilling machine cutting a small hole in the rock, and the cut rock is conveyed out of the machine by a system of conveyor belts.

7.1.2 The tunnelling machines, especially the cutter heads have to be specially built for specific strata. The designers usually design the cutters on the basis of the crushing strength of the rock through which the tunnel is to be driven.

7.1.3 In self supporting rock or rock requiring very little support, no shield is provided. The machine while excavating, is usually held in position by hydraulic jacks pressing against the sides of the tunnel. Propelling forward is also similarly achieved.

7.1.4 In soft strata requiring supports, the steel supports provide the normal reaction for the hydraulic jacks.

7.1.5 In clays and soils, the machines are fitted with shields extending over the full machines and the cutter heads. The system of supports is usually with precast concrete segments. The machine incorporates a mechanical system for speedy erection of the heavy concrete segments.

7.1.6 All machines are invariably guided by the 'laser' system in alignment.

7.1.7 The speeds achieved are very high compared to traditional methods. Speeds of 1·5 m/h or 30 m per day are not uncommon. These machines to be effective require an equally efficient and fast muck removal system.

7.1.8 The machine facilitates speedly excavation, a clean cut rock face with practically no overbreaks and comparatively less vibration of the strata. No recommendations can be made at the present on the use of these machines in India.

8. OPERATIONS

8.1 Sequence of Operations for Construction of Tunnels — For a tunnel driven in soft strata with traditional methods, the following operations are required:

a) Marking tunnel profile;

b) Setting up and drilling — Necessary for soft rocks only where blasting is necessary. For soils excavation is done without blasting and would require ' forepoling methods ' (*see* **10.1**);

c) Loading explosives and blasting, if required;

d) Removing the foul gases after blasting;

e) Checking misfires;

f) Scaling;

g) Mucking;

h) Erection of supports, or guniting, or shotcreting with/without rock bolts. The process of guniting and shotcreting should generally be concurrent with mucking; the muck pile being used as a platform to gunite/shotcrete the crown and adjoining areas. The lower parts may be gunited/shotcreted after mucking is complete; and

j) In case of use of only steel supports without gunite or shotcrete, the steel supports should be erected after mucking and followed by ' initial concrete ', blocking, lagging and packing. This operation should be done after mucking but simultaneous with the drilling for blasting of the next round.

8.2 Drilling — For blasting a rock in soft strata, it is necessary to drill holes for charging the explosives. The drilling pattern should be worked out by experiments for each particular work and should be modified, if necessary, for every round of blasting to control the overbreaks. The drilling pattern should be such, as to ensure minimum overbreak with minimum or no underbreak and least amount of explosives per unit volume of excavation. Adequate safety precautions shall be taken during drilling operations in accordance with IS : 4081-1967*.

8.3 Equipment — Holes shall be drilled by using pneumatically operated rock drills in conjunction with pneumatic pushers and/or auto-feeds with

*Safety code for blasting and related drilling operations.

ladders or drifters mounted on column bars or drill carriages, as may be found suitable. Only wet drilling shall be permitted. Number of drills is governed by the area of the face of the tunnel. It is generally recommended that one drill is required for each 4 to 5 m^2 face area.

8.4 Diameter of Hole — The diameter of hole at its deepest point shall be at least 6 mm more than the diameter of the cartridge.

8.5 Drilling Pattern — The various patterns used are specified in IS : 5878 (Part II/Sec 1)-1970*. For tunnels in soft strata the following patterns are recommended:

a) Horizontal wedge,
b) Fan cut, and
c) Cylinder cuts.

8.6 Blasting — The recommendations given in IS : 5878 (Part II/Sec 1)-1970* shall be followed. It is, however, recommended that in soft strata instantaneous blasting of a large number of holes should be avoided, and delay detonators should invariably be used to reduce vibrations. Where delay detonators are not available then blasting by the ordinary detonators and fuse coils should be done and delay achieved by adjusting the lengths of the fuse coils.

8.7 Mucking — The recommendations given in IS : 5878 (Part II/Sec 2)-1971† shall be followed.

8.8 Ventilation, Dewatering — Recommendations given in IS : 5878 (Part II/Sec 2)-1971† shall be followed.

8.9 Construction of Supports and Shotcreting — For erection of steel supports and shotcreting the recommendations given in IS : 5878 (Part IV)-1971‡ shall apply. The design of tunnel supports shall be done in accordance with IS : 4880 (Part VI)-1971§.

8.9.1 When multiple drift method is used, the practice given in Appendix A may be adopted for supporting the roof and sides.

9. USE OF TIMBER IN TUNNELS

9.1 Timber has to be used in supporting the rock face from steel ribs, in the form of blocking, bracing and lagging. Timber is also used in forepoling methods.

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*Code of practice for construction of tunnels: Part II Underground excavation in rock, Section 1 Drilling and blasting.

†Code of practice for construction of tunnels: Part II Underground excavation in rock, Section 2 Ventilation, lighting mucking and dewatering.

‡Code of practice for construction of tunnels: Part IV Concrete lining.

§Code of practice for design of tunnels conveying water: Part VI Tunnel supports.

9.2 It is recommended that use of timber in underground work should be minimized as far as practicable, since timber once fixed can rarely be removed safely and is likely to deteriorate and prove a source of weakness. Total prohibition of timber is, however, not practicable. Properly treated timber may be used.

9.3 Lagging, whenever necessary, may be of the following three types:

a) Timber pieces used as lagging and as shuttering for initial concrete to be removed later,

b) Chain link and shotcreting, and

c) Precast concrete sleepers.

9.4 Collar braces for supports may be timber or steel. Timber should be removed just prior to lining.

9.5 It is very essential to ensure that the roof load is transferred from the excavated tunnel profile to the permanent supports properly. This may be achieved with timber wedges, hand-packed rubble or moist sand shot through concrete pumps or placers. If the gap between the top of the concrete lagging and the tunnel profile is not excessive, the same could be filled with grout. In case of rubble packing, the voids in the rubble should be filled with grout.

9.5.1 Where space does not permit this, timber blocking shall be used and left in position.

9.6 For cribbing in case of large overbreaks, use of concrete sleepers, possibly of light weight aggregates, should be considered in place of timber.

9.7 Shotcreting with or without reinforcement is recommended to be used to reduce the use of supports and timber.

APPENDIX A

(*Clause* 8.9.1)

METHOD OF SUPPORTING ROOF AND SIDES IN MULTIPLE DRIFT METHOD

A-1. DETAILS OF METHODS

A-1.1 Some common methods of supporting the roof and sides where tunnelling is done using multiple drift method are given in **A-1.1.1** to **A-1.1.5**.

A-1.1.1 *American Method* — In this method (*see* Fig. 5A) a drift is driven at top of arch, in which a cap timber is carefully set supported by two posts resting on a side. The sides of the drift are then broken out

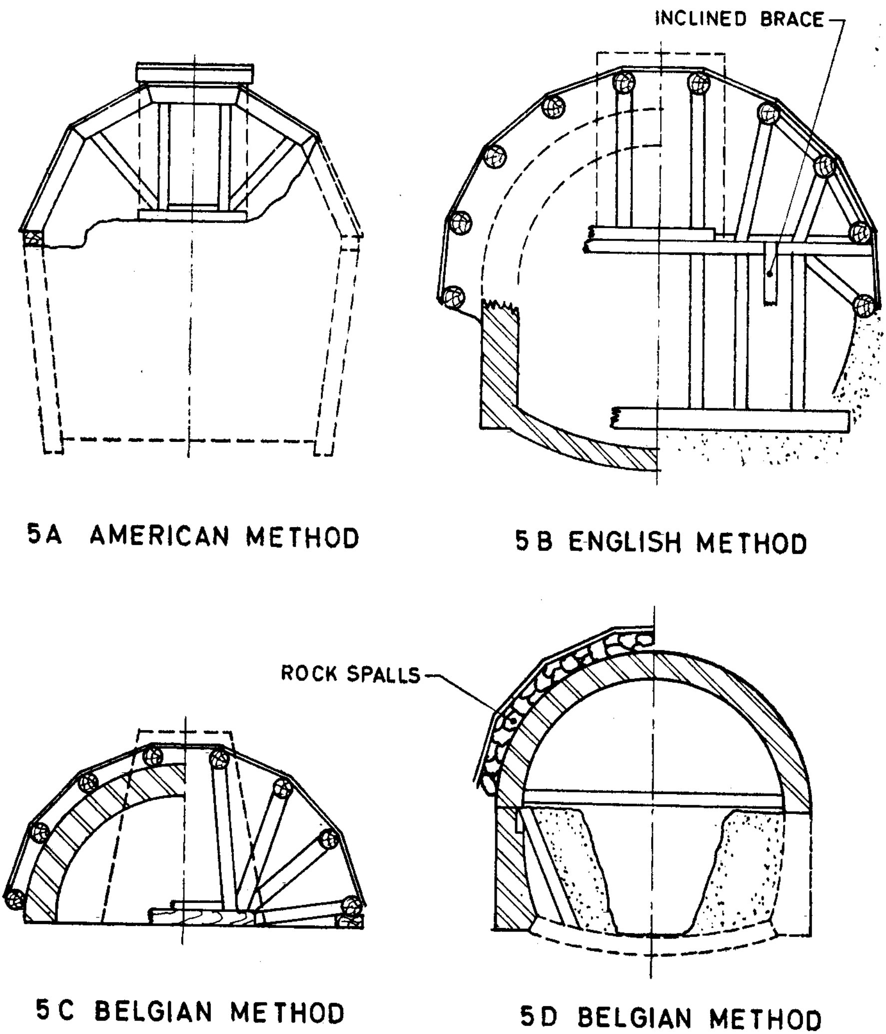

FIG. 5 METHODS OF SUPPORT

and the shoulder timber placed supported by an inclined strut from the sill. The top heading is then widened out until the wall plates can be set in place. The wall plates should be long. Next, the legs are placed and wedged tight to take the load off the centre sill, after which temporary posts are removed. The wall plates are then under-pinned with the plumb posts by cutting out a short wall drift in the bench, deep enough to take either one or two posts.

A-1.1.2 *English Method* — In this method (*see* Fig. 5B) a centre top heading is driven 5 to 8 m ahead of the masonry arch. In this drift, two heavy timbers known as crown bars are erected. The back ends of the timbers are blocked off the arch and the front ends are carried on posts resting on a sill in the floor of the drift. The drift is then widened and another crown bar and lagging placed. This method is continued until the entire arch is carried on longitudinal bars. The forward posts are then underpinned and supported on posts from a sill at floor level.

A-1.1.3 *Belgian Method* — In this method (*see* Fig. 5C and 5D) the top centre heading is driven first and two crown bars set as in the English method, being supported on sills on the bench. The tunnel is widened in the same manner, the additional bars being carried on the same mud sills. A trench is excavated down to grade in the centre of the tunnel and a muck track laid therein. From this trench, side cuts are made to the edge of the arch which at that point is carried on shores from the floor. Pockets are then cut under the arch and the masonry side walls built to underpin the arch. The shores are set and the pockets excavated in alternate spaces until the arch is entirely supported on masonry.

A-1.1.4 *German Method* — This method employs three drifts — one at the crown and two at the bottom along the walls.

A-1.1.5 *Austrian Method* — In this method a centre cut is taken for the full height of the tunnel. This is then widened to full face to allow short sections of masonry to be completed.

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TO

IS:5878(Part III)-1972 CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART III UNDERGROUND EXCAVATION IN SOFT STRATA

Alteration

(First cover page, pages 1 and 3, title) - Substitute the following for the existing title:

'CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART III UNDERGROUND EXCAVATION IN SOFT STRATA'